UNITED STATES DEPARTMENT OF AGRICULTURE

FOREST SERVICE

RS-INT
M-1, R
1935 Transect Study

March 24, 1936

A PRELIMINARY STUDY OF FACTORS AFFECTING ESTABLISHMENT OF PONDEROSA PINE AND DOUGLAS FIR SEEDLINGS IN CENTRAL IDAHO

by

Andrew R. McConkie and Edwin L. Mowat
Intermountain Forest and Range Experiment Station

RS-INT
M-1, R
1935 Transect Study

March 24, 1936.

A PRELIMINARY STUDY OF FACTORS AFFECTING ESTABLISHMENT OF PONDEROSA PINE AND DOUGLAS FIR SEEDLINGS IN CENTRAL IDAHO

By Andrew R. McConkie and Edwin L. Mowat
Intermountain Forest and Range Experiment Station

Table of Contents

RS-INT
M-1, R

March 24, 1936

A PRELIMINARY STUDY OF FACTORS AFFECTING ESTABLISHMENT OF PONDEROSA PINE AND DOUGLAS FIR SEEDLINGS IN CENTRAL IDAHO

By Andrew R. McConkie and Edwin L. Mowat

Introduction

The problem of obtaining adequate reproduction to replace stands removed by logging in central Idaho is rapidly becoming more evident. Of necessity, if these areas are to carry a part of the timber burden they must be restocked, principally by natural advance or subsequent reproduction or a combination of both.

Origin, Purpose, and Scope of Study

During the summer of 1935 the Intermountain Forest and Range Experiment Station of the United States Forest Service initiated a preliminary study of reproduction on the Boise Basin area. A heavy seed crop in 1934 and high precipitation during April 1935 resulted in the appearance of numerous seedlings for field observation.

The purpose of this study was primarily to determine the principal factors affecting the occurrence of seedlings, and the effect of these factors upon the survival of seedlings up to the fall of the first year. At the outset it was recognized to be a preliminary study, and as such it was not believed that an accurate weighting of factors could be accomplished. It was hoped that such a study would serve as a connecting link between general observations of reproduction conditions in the field and the intensive measurement of effects of various physical factors under artificial control.

This study differs from Otter's "Studies in Natural Reproduction in Central Idaho", made in 1932, in that it covers a much wider range of factors and conditions, but deals only with reproduction during its first year. Otter selected his seedlings and ran random strips as a check. The data for this study were obtained from samples located at random on a base map in the office.

Description of Study Area

The areas on which the field observations were made are located in the Bannock and Pine Creek drainages, about 3 to 6 miles to the southeast of Idaho City, Idaho. The Bannock Creek study area includes sections 4, 5, 6, 8, 9, 16, T. 5 N., R. 6 E., Boise Base and Meridian. The Pine Creek area includes sections 7, 18, T. 5 N., R. 6 E., and sections 1, 12, 13, T. 5 N., R. 5 E. The soil is of granitic origin varying from raw, rotten granite on some south slopes to sandy loam and loam near creek bottoms and on the more densely vegetated north aspects.

In central Idaho it is characteristic of ponderosa pine to be in pure stands on the southerly aspects and mixed with Douglas-fir on the north. The lesser vegetation on the south slopes is commonly composed of bitterbrush, balsamroot, and downy chess; sometimes only annuals such as fireweed, kitchen weed, and phacelia are found. On areas that are relatively flat pine grass and pine sedge are usually found under a pure stand of ponderosa pine. It is characteristic on north slopes to find mixed stands of pine and fir with an understory of Douglas-fir reproduction and ninebark, with various species of grass underneath.

The Bannock Creek area is included in the Experimental Forest and contains in the main a stand of virgin timber. All age classes are represented in the stand, but it is made up principally of mature and overmature trees with advance reproduction occupying the larger openings within and downy chess and balsamroot occupying those near the edge of the stand. On the higher south and west exposures the stand grades out into a "protection type" of scattered trees or into a treeless brush-grass type. The forest floor is covered with a relatively thin layer of debris, averaging about 1/2 inch and rarely exceeding 6 inches in depth.

Pine Creek is located about 2 miles to the west of Bannock Creek, partially within the national forest and partially on state and private holdings. This area was logged over by the Boise-Payette Lumber Company during 1933, using an economic timber selection method. About 30 percent by volume of the trees were left as below the economic limit or as seed trees. Tractor skidding was used leaving a considerable amount of debris and resulting in a noticeable amount of injury to advance reproduction. Slash was piled and burned on about half the area covered by the transects; no disposal on the other half. In general there is more grass on the Pine Creek area, and weed vegetation on southern slopes has attained greater height and density.

<u>Precipitation and Soil Moisture</u>

As a basis for comparing moisture conditions during the time of study with "normal" precipitation, table Ia gives a comparison with the previous 10-year average by months.

TABLE Ia
Deviation of 1935 Precipitation
From 10-Year Average. 1925-34
(Idaho City, Idaho)

	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	April	May	June	July	Aug.	Sept.
10-year av.				3.30	2.21	2.24	1.20	1.13	.82	.34	.40	.52
1935				2.51	.92	1.78	3.20	1.05	.11	.11	00	00
Deviation				-.79	-1.29	-.46	+2.00	-.08	-.71	-.23	-.40	-.52

Methods of Study

Field Procedure

Random transects were chosen along the routes of the 1933-43 cruise lines on a base map in the office (see map). They were located in such a way as to include the different types and conditions found on the areas. The transects were not evenly spaced throughout the two drainages because to have done so in the time allowed for the study would have meant wasting much time on unproductive sections and failing to obtain a representation of certain slopes and other conditions. Thus, the survey is not an accurate inventory of the total area and was not intended as such. If the transects are assumed to properly sample a 5-chain wide strip, as did the cruise lines along which they were located, they may be said to represent an area of 304 acres, 4 percent of which was actually examined. However, they are scattered over a much larger area than this so that it is difficult to say exactly what they represent on the area basis.

The deficiency in precipitation during all the summer months naturally resulted in unusually low soil moisture content. That soil moisture was a critical factor on some sites even before the date of initiation of this study is indicated by the figures in table Ib. This table gives available soil moisture at three depths in three selected locations in the Bannock Creek area on five different dates. The data are based upon duplicate samples taken in connection with a root development study of pine and fir seedlings. They may be considered here only for indicating general trends on the area, not specific relations for any group of seedlings studied.

Table Ib
Available Soil Moisture, Bannock Creek Area
(% Based on Oven-Dry Weight)

Depth	6/8/35	6/20/35	7/1/35	7/15/35	8/1/35
			(Flat)		
5"	[illegible]	5.8	8.6	0	2.9
9"	6.3	4.0	2.4	-.3	3.3
18"			2.3	.2	-.8
			(South Exposure)		
5"		1.7	.3	-3.5	-1.4
9"	4.1	1.8	1.4	1.2	2.8
18"			1.1	1.7	-1.3
			(North Exposure)		
5"	[illegible]	.5	-2.1	1.5	-.5
9"		1.1	0	-.5	-1.1
18"			.2	0	1.0

In Pine Creek 140 chains of transect are along the permanent transect lines on the seven permanent methods of cutting plots established in 1933. Since these plots are scattered throughout the area, and the methods of cutting used were not widely different from the general method, the transects are taken to be comparable with those along the cruise lines. Data taken in the annual study made of the permanent transects were used which accounts for the lack of certain areal data for the Pine Creek drainage, in relation to type of vegetation, soil surface, litter ratio, debris, shade, and seed tree class.

The transects were 20 links wide and each was a continuous strip to predetermined boundaries. Each transect was measured with a trailer chain and abney. A stake was set at the end of each chain. The distance was then measured back from the stake on the slope to each individual seedling found within 10 links of either side of the trailer chain. The distance was recorded with the seedling data as a basis for future location. A pin of #9 wire with the top bent twice at right angles( ) was placed by each seedling or group, usually 3 inches away on the down hill side. Pins were removed when the seedlings died.

At the end of each chain, on the left-hand side, a 2-milacre plot was described with the same detail as each seedling. These data were used in bringing out the area comparisons used in this study.

Data Recorded - Code Sheet

Each seedling was closely examined and described by use of the following code sheet.

A. Species

    P. Ponderosa pine
    F. Douglas-fir

B. Group (number growing together)

C. Aspect (to nearest octant)

D. Slope

    1. 0-5%
    2. 6-20%
    3. 21-40%
    4. 41-70%
    5. 71 %

E. Type (the immediate type of vegetation surrounding the seedling and most likely to affect it by root competition, shade, etc. Where more than one seemed important the more remote or less effective type was indicated as secondary.)

    1 R. Ponderosa pine reproduction
    1 P. Ponderosa pine poles
    1 IM. Ponderosa pine immature
    1 M. Ponderosa pine mature
    1 OM. Ponderosa pine overmature
    2 R. Douglas-fir reproduction
    2 P. Douglas-fir poles
    2 IM. Douglas-fir immature
    2 M. Douglas-fir mature
    2 OM. Douglas-fir overmature
    3. Brush
    4. Grass
    5. Weeds
    0. None or Bare (No vegetation near enough to be effective).

F. Soil surface

    1. Mineral soil, little or no charcoal
    2. Mineral soil, mixed with ash and charcoal
    5. Litter or humus on mineral soil
    5S. Skid Trail
    6. Rotten wood

G. Litter depth (to mineral soil)

0. None
1. Very light, soil not hidden
2. .25 to .5 inch
3. .6 to 1 inch
4. 1.1 to 1.5 inches
5. 1.6 inches and up
6. Rotten wood

H. Debris (nonliving protective cover other than litter)

0. None
1. Stump
2. Log (over 4" diameter)
3. Limbs, bark, trash (over 1" diameter) sufficient to conserve soil moisture)
4. Rocks

I. Shade

H. Heavy
P. Partial
0. None
1. Morning and/or afternoon
2. A.M. and/or P.M. and part of midday
3. Shaded 11:30 to 3:30 only (midday)
4. Shaded 11:30 to 3:30 and A.M. or P.M.
5. Full shade all day

J. Vegetation density (within a 1-foot radius) estimated in percent using area covered as a base.

K. Vegetation height

Given in inches for vegetation included in J.

L. Soil depth (to nearest foot)

1. 1' in depth
2. 2' in depth
3. 3' in depth
4. 4' and over in depth

M. Soil texture (by ocular examination)

1. Gravelly sandy loam
2. Sandy loam
3. Loam

N. Seed tree zone

1. Within 10 feet

2. 11 to 25 feet
3. 26 to 50 feet
4. 51 to 100 feet
5. Over 100 feet (still a fair chance to seed)
6. Over 100 feet (poor chance to seed)
(Where there are seed trees in certain zone on two or more sides, recorded as one zone closer.)

O. Seed tree class (Dunning's classes by numbers)

P. Situation (special situations)

G. Gopher mounds
T. Trails
1. Within probably reach of the water table
2. Road cut or fill or old ditch bank

Q. Vigor of seedlings

1. Good - excellent
2. Medium
3. Poor
D. Dead
M. Missing

R. Cause of death (determined by inspection)

1. Drought (including heat killing, drought, and insolation)
3. Livestock browsing and trampling
4. Rodents

Analysis of Data

The data for each seedling were placed on a 3" x 5" index card in the office, and each group of cards were then sorted to determine figures shown in this report.

At the outset, moisture was recognized as an important factor in seedling survival. The first inspection of seedlings was made July 27 to September 5, 1935. This was sufficiently late in the season to allow other factors than moisture to show. The second inspection was made October 8, 9, and 10 and was soon followed by a rain so that most of the seedlings alive at this time probably would live through the season.

There were sufficient Douglas-fir seedlings on the Bannock Creek area to analyze as a comparison with the ponderosa pine. Only 36 Douglas-fir were encountered on the Pine Creek transects. This number was believed to be insufficient to use as a comparison except in number. It is interesting to note, however, that this is a cut-over area with rather severe exposure.

It was evident from the beginning that stream-bottom seedlings in Bannock Creek could not be considered with those of the rest of the virgin forest, both because of exceptional disturbance to this site and because of moisture supply so favorable as to outweigh all recorded factors. This group of seedlings is, therefore, excluded in all the following tables and discussion.

TABLE II

Basis of Natural Reproduction Study

1	2	3	4	5	6	7	8
Location	Species	Chains transect	Acres transect	Total seedlings	Average seedlings per acre	Number seedlings surviving	Number seedlings Surviving per acre
Bannock	Pine	340	6.8	624	91.8	110	16.2
Bannock	Fir	340	6.8	219	32.2	73	10.7
Pine Cr.	Pine	268	5.36	253	47.2	108	20.1

As shown in table II, the average occurrence of pine seedlings per acre on the Bannock Creek virgin area was twice as great as that of the Pine Creek cut-over area. In contrast to this, however, the final inspection shows a greater number surviving per acre in Pine Creek than in Bannock Creek.

The figures given for total number of seedlings are conservative in that some had already died or disappeared at the time of the first examination of the transects. Records were made for 278 seedlings found dead at first inspection, well distributed through the various sites and types, but as not all dead seedlings could be recorded they are used in the following tables and discussion only for the analysis of causes of death.

Relation of each Factor to Seedling Occurrence and Survival

Aspect.

TABLE IIIa

Effect of Aspect on Ponderosa Pine Seedlings
(Bannock Creek)

Aspect	% Total area	Live seedlings	% Total seedlings	Av. no. per unit area*	% Survival	% Seedlings killed by Drought etc.	Live-stock	Rodents
N	14.2	21	4.7	0.33	42.7	82.3	11.8	5.9
NE	6.5	14	2.6	.40	28.5	92.3	7.7	0
E	7.1	34	3.7	.52	14.7	79.2	5.7	15.1
NW	23.3	104	16.7	.72	16.3	84.6	5.1	10.3
SE	10.0	38	6.4	.64	10.5	79.3	0	20.7
S	9.1	64	10.1	1.11	6.3	76.3	.8	22.9
SW	12.7	157	25.1	1.98	23.6	82.2	3.9	13.9
W	17.1	189	30.7	1.80	15.3	84.9	4.7	10.4
Total	100.0	621	100.0	1.00	17.6	81.8	3.9	14.3
Northerly	51.1	173	27.7	.54	20.3	83.5	6.0	10.5
Southerly	48.9	448	72.3	1.48	16.4	81.5	3.1	15.4

* "Av. No. per Unit Area" is a relative figure, the ratio of Col. 4 to Col.2; a figure of 1.00 indicates that occurrence of seedlings on that particular site is average for the area--that it is neither especially favorable (ratio above 1.00 nor unfavorable (ratio below 1.00). The number may be converted to number per acre by multiplying by the appropriate average number of seedlings per acre given in table II.

TABLE IIIb

Effect of Aspect on Ponderosa Pine Seedlings

(Pine Creek)

Aspect	% Total area	Live seedlings	% Total seedlings	Av. no. per unit area	% Survival	% Killed by 1*	3	4
N	9.0	16	6.3	.70	68.8	87.5	0	12.5
NE	2.6	9	3.6	1.38	77.8	100.0	0	0
E	6.0	36	14.4	2.40	19.4	93.3	0	6.7
NW	7.8	24	9.5	1.21	62.5	66.7	0	33.3
SE	4.8	7	2.7	.55	57.2	100.0	0	0
S	16.8	30	11.7	.69	40.0	89.5	5.2	5.3
SW	26.5	61	24.1	.92	26.2	88.9	3.7	7.4
W	26.5	70	27.7	1.05	51.4	94.8	2.6	2.6
Total	100.0	253	100.0	1.00	42.7	90.1	2.5	7.4
Northerly	25.4	85	33.8	1.33	47.1	88.0	0	12.0
Southerly	74.6	168	66.2	.89	40.5	91.0	3.6	5.4

* Code numbers used in this and succeeding tables for cause of death indicate: 1. Drought, etc., 3 Livestock, 4. Rodents (See code sheet).

TABLE IIIc

Effect of Aspect on Douglas-Fir Seedlings

(Bannock Creek)

Aspect	% Total area	Live seedlings	% Total seedlings	Av. no. per unit area	% Survival	% Killed by 1	3	4
N	14.2	69	31.5	2.21	31.9	80.0	14.0	6.0
NE	6.5	11	5.2	.80	63.7	75.0	25.0	
E	7.1	48	21.9	3.09	41.7	75.8	9.0	15.2
NW	23.3	59	26.9	1.15	18.6	87.7	4.1	8.3
SE	10.0	3	1.4	.14	0	100.0		
S	9.1	0	0	0	0			
SW	12.7	3	1.4	.11	0	100.0		
W	17.1	26	11.7	.68	50.0	93.3		6.7
Total	100.0	219	100.0	1.00	33.3	83.6	8.2	8.2
Northerly	51.1	187	85.5	1.67	32.1	81.6	9.6	8.8
Southerly	48.9	32	14.5	.30	40.6	95.6		4.4

The effect of aspect upon the young seedling is felt chiefly through its reaction to varying degrees of soil moisture, light, soil temperature, and plant competition. As brought out in table IIIa the germination and establishment of ponderosa pine seedlings in the virgin stand is least on the northerly slopes and shows a remarkably direct increase with exposures receiving more direct light. On the cut-over area, however, it is again reduced if the exposure is too severe. Table IIIb shows the greatest occurrence on those aspects of intermediate exposure.

The best final survival on both areas was found to be on the north and northeast aspects. This is likely due to better moisture conditions on these sites and was especially brought out by the dry summer of 1935.

Douglas-fir seedlings in contrast being more tolerant of shade and having a more surficial root system were practically confined to protected aspects. The highest survival percent is shown for the northeast aspect with the greatest number of seedlings per acre surviving on the east aspect.

A comparison of all northerly and all southerly aspects is given in the last two lines of tables IIIa, b, and c. In this combination, east aspect is placed in the north group, west in the south group. While such a grouping into two classes is customary and is desirable for simplification, it should be noted that some relations of possible significance are thereby obscured. For example, in table IIIa, the variation in survival among the eight aspects is much greater

than the average difference of northerly and southerly. True north shows more than double the survival on all northerly, and true south shows less than half the survival on all southerly. The averages in table IIIc would indicate that survival of Douglas-fir seedlings is greater on southerly than on northerly aspects - a conclusion of doubtful truth resulting from the heavy weight carried by the 26 seedlings on the west, where survival was high.

In analyzing the effect of each factor separate figures were compiled for seedlings on northerly and on southerly aspects. In most cases, the trend of relation was the same on the two aspects; in a few cases, different. In order to keep the following discussion and tables as simple as possible, this separation is omitted unless a significant difference was apparent between the two aspects.

Cause of Death

Determination of cause of death was made by field inspection of the remains of the individual seedling and site upon which it had been growing. To avoid confusion all dead seedlings were placed in one of three classes: (1) drought or heat killed, (3) dead from livestock browsing or trampling, or (4) killed by rodents. If the entire dead seedling was present with no other evidence of injury, it was placed in group (1). In case the seedling was broken, injured, or missing entirely, cause of death was arrived at by a joint inspection of the seedling when found and any evidence of disturbance of its growing site. Where two of these factors were obviously involved, the cause most likely to have caused its death was used.

The evidence of rodent kill on these areas consisted, in many cases, of a small hole about an inch deep dug or scratched at the site of the seedling, either with or without remains of the seedling. In a few cases, the seedling had been nipped off at or near ground level; and in still other cases where the seedling was missing, there were freshly chewed or disturbed cone scales or seed husks immediately adjacent to the site. The kinds of rodents responsible were not determined. On portions of strip 23-W, where a large proportion of rodent kill was noted, there were numerous old gopher mounds, but rodent kill was also found on other transects where there were no such mounds.

Cattle were grazed on both study areas throughout the season. Sheep were excluded from Bannock Creek but grazed over the state and private lands in Pine Creek. Livestock or grazing damage as here recorded was predominately from trampling, though there was occasional browsing, probably accidental.

Of the total deaths of pine seedlings in Bannock Creek, 81.8 percent were ascribed to drought, 3.9 percent to livestock, and 14.3 percent to rodents. The significant loss due to rodents is higher than might be anticipated for seedlings in this stage of development. The relatively lower grazing loss and higher rodent loss on southerly than on northerly aspects (table IIIa) probably has little or no significance as the relations do not hold consistently for the Pine Creek area and for Douglas-fir (tables IIIb and IIIc). On the cut-over area drought was charged with 90.1 percent of the loss, grazing 2.5 percent, and rodents 7.4 percent. The lower grazing loss on the cut-over area

(it may not be significantly different) could presumably be ascribed to protection of certain spots by slashing, although this relation was not particularly evident in the field. The reason for lower rodent damage is not apparent, but the difference seems to be a real one. Of the losses of Douglas-fir seedlings, 83.6 percent were due to drought, 8.2 percent to grazing, and 8.2 percent to rodents. Kill by livestock was thus proportionately higher, that by rodents proportionately lower, than for pine on the same area.

In the following discussion further comment is not made on cause of death unless it appears to exert undue influence on relationships shown in the accompanying tables.

The relative percentages shown for cause of death are based on all dead seedlings described, regardless of whether or not they were dead at the first inspection. Since the major causes of death likely vary greatly throughout the season, these figures are used principally to check variations within the tables.

Slope

TABLE IVa
Effect of Slope on Ponderosa Pine Seedlings
(Bannock Creek)

Slope %	% Total area	No. live seedlings	% Total seedlings	Av. no. per unit area	% Survival	% Killed by 1	3	4
0-5	6.4	117	18.8	2.94	19.7	89.7	4.1	6.2
6-20	20.3	243	39.1	1.93	18.5	87.7	1.4	10.9
21-40	43.9	197	31.7	.72	15.2	75.5	4.5	20.0
41-70	29.4	65	10.4	.35	16.9	89.4	3.9	6.6
71 +	0	0	0	0	--			
Totals	100.0	622	100.0	1.00	17.6	82.5	3.5	14.0

TABLE IVb

Effect of Slope on Ponderosa Pine Seedlings

(Pine Creek)

Slope %	% Total area	No. live seedlings	% Total seedlings	Av. no. per unit area	% Survival	% Killed by 1	3	4
0-5	5.6	25	9.9	1.77	64.1	88.9		11.1
6-20	42.2	100	39.5	.92	52.0	89.1		10.9
21-40	39.9	115	45.5	1.14	30.2	91.2	4.4	4.4
41-70	11.9	13	5.1	.41	25.0	100.0		
71+	.4							
Totals	100.0	253	100.0	1.00	41.9	91.0	2.4	6.6

TABLE IVc

Effect of Slope on Douglas-Fir Seedlings

(Bannock Creek)

Slope %	% Total area	No. live seedlings	% Total seedlings	Av. no. per unit area	% Survival	% Killed by 1	3	4
0-5	6.4	11	5.0	.78	72.7	66.7	33.3	
6-20	20.3	22	10.1	.50	45.4	50.0	25.0	25.0
21-40	43.9	77	35.1	.80	39.0	83.6	8.2	8.2
41-70	29.4	108	49.3	1.68	23.1	50.	50.	
71+	0	1	.5		0			
Totals	100.0	219	100.0	1.00	33.3	83.6	8.2	8.2

The number of pine seedlings per unit area shows a decrease with increased percent slope, this tendency being much more pronounced in the virgin forest, as brought out in tables IVa and IVb. Pine seedling survival on these areas is also higher on the areas of least slope. Douglas-fir seedlings on the other hand had a higher occurrence per unit area on steep slopes but the lowest percent survival. The lower survival on steeper slopes probably results in part from excessive soil drainage. The depth of root penetration during the early summer months is undoubtedly an important influence on the seedling survival. The taproot must of necessity be much longer on steep slopes than on level ground to receive an equal amount of protection from drying out.

The contrasting trends of occurrence of pine and of fir in relation to slope is partially explained by the interrelations of slope and aspect. It was shown above that pine seedlings were more abundant on southerly, fir on northerly slopes. In the Bannock Creek drainage, steeper slopes occur principally on north aspects, as indicated in table IVd. Hence the apparent preference of Douglas-fir for steep slopes is to

TABLE IVd

Proportions of Different Slopes and Aspects in Percent of Total Area

Area	Aspect	Slope %					
		0-5	6-20	21-40	41-70	71 +	ALL
Bannock	Northerly	1.3	6.6	22.8	20.4	-	51.1
	Southerly	5.3	13.9	21.0	8.7	-	48.9
Pine Cr.	Northerly	1.1	13.2	10.0	1.1	-	25.4
	Southerly	4.5	29.1	29.8	10.8	0.4	74.6

some extent one of preference for northerly aspects. However, even on north exposures fir seedlings were as abundant on steep as on gentle and medium slopes, probably because the steeper the north slope the greater the shade and protection from the sun. On southerly exposures, where the majority of pine seedlings were found, the steeper slopes are as a rule the hotter and drier ones.

A factor of minor importance which may affect the occurrence of seedlings of either species on any aspect is the tendency for seeds to become lodged on the less steep portions of a slope.

Soil Depth

TABLE V a

Effect of Soil Depth on Ponderosa Pine Seedlings

(Bannock Creek)

Depth	% Total area	No. live seedlings	% Total seedlings	Av. no. per unit area	% Survival	% Killed by 1	3	4
1	6.1	4	1.4	.23	0	100.0		
2	37.7	71	12.4	.33	15.5	96.5	2.4	1.1
3	35.5	243	41.9	1.18	16.0	91.9	4.9	3.2
4	20.7	261	45.3	2.19	22.0	85.5	4.4	10.1
Total	100.0	579	100.0	1.00	17.6	90.2	4.2	5.6

TABLE V b

Effect of Soil Depth on Ponderosa Pine Seedlings

(Pine Creek)

Depth	% Total area	No. live seedlings	% Total seedlings	Av. no. per unit area	% Survival	% Killed by 1	3	4
1	9.0	25	15.0	1.67	23.7	88.9		11.1
2	26.0	100	21.4	.82	18.5	89.1		10.9
3	29.5	115	29.6	1.00	45.3	91.2	4.4	4.4
4	35.5	13	34.0	.96	64.0	100.0		
Total	100.0	253	100.0	1.00	41.9	90.3	2.4	7.3

TABLE V c

Effect of Soil Depth on Douglas-Fir Seedlings

(Bannock Creek)

Depth	% Total area	No. live seedlings	% Total seedlings	Av. no. per unit area	% Survival	% Killed by 1	3	4
1	6.1	9	4.2	.69	0	88.9		11.1
2	37.7	51	24.1	.64	29.4	83.8	13.5	2.7
3	35.5	117	55.2	1.55	35.9	87.6	6.2	6.2
4	20.7	35	16.5	.80	40.0	80.9	14.3	4.8
Total	100.0	212	100.0	1.00	33.3	86.0	8.5	4.6

It is evident from the above tables that soil depth is much more important in determining the survival of both Douglas-fir and pine seedlings late in the summer than during the early spring months. On only the virgin area was there a marked difference in the number per unit area on different soil depths at the first inspection. It is probable that there was not sufficient moisture held in the more shallow soils to support the seedlings during such a long, dry summer as that of 1935. At the second inspection the ground was very hard and dry to a depth of 8 or 9 inches. Without penetrating more than 12 inches into the soil, it would be practically impossible for the seedlings to live on these sites during a dry season. As was expected, soil depth, if greater than 1 foot, exerted less influence on Douglas-fir survival due to the nature of its root system.

Soil Texture.

TABLE VI a

Effect of Soil Texture on Ponderosa Pine Seedlings

(Bannock Creek)

Texture class	% Total area	No. live seedlings	% Total seedlings	Av. no. per unit area	% Survival	% Killed by		
						1	3	4
1	14.2	93	15.7	1.11	17.2	87.7	1.7	10.6
2	84.2	523	83.3	.99	17.5	88.3	4.5	7.2
3	1.6	6	1.0	.64	0	87.5		12.5
Total	100.0	622	100.0	1.00	17.6	88.2	3.7	8.1

TABLE VI b

Effect of Soil Texture on Ponderosa Pine Seedlings

(Pine Creek)

Texture class	% Total area	No. live seedlings	% Total seedlings	Av. no. per unit area	% Survival	% Killed by		
						1	3	4
1	6.0	14	5.5	.92	21.2	100.0		
2	90.0	229	90.5	1.01	45.0	89.3	2.9	7.8
3	4.0	10	4.0	1.00	20.0	87.5		12.5
Total	100.0	253	100.0	1.00	41.9	90.1	2.5	7.4

TABLE VI c

Effect of Soil Texture on Douglas-Fir Seedlings

(Bannock Creek)

Texture class	% Total area	No. live seedlings	% Total seedlings	Av. no. per unit area	% Survival	% Killed by		
						1	3	4
1	14.2	38	17.4	1.23	47.3	48.1	25.9	26.0
2	84.2	163	74.3	.88	29.0	90.1	4.8	4.1
3	1.6	18	8.3	5.18	44.4	100.0		
Total	100.0	219	100.0	1.00	33.3	83.0	8.5	8.5

In Bannock Creek the highest number of pine seedlings per unit of area, and also the greatest survival was in gravelly sandy loam (Class 1) and sandy loam (Class 2). Sandy loam in the cut-over area shows an especially high survival percentage. This appears to tie up with the common observation that ponderosa pine prefers a light soil. It may be indirectly due partly to lack of other types of vegetative competition on this type of soil. Douglas-fir, as brought out in table VIc, shows high preference for straight loam soil (Class 3). Loam soils were usually encountered in the moist sites, which would naturally favor Douglas-fir as well as other vegetation.

Too much significance should not be attached to the apparent differences shown for soil texture inasmuch as the sandy loam type was so predominant throughout and texture was only an ocular field estimate.

Debris

TABLE VII a

Effect of Debris on Ponderosa Pine Seedlings

(Bannock Creek)

Debris	% Total area	No. live seedlings	% Total seedlings	Av. no. per unit area	% Survival	% Killed by		
						1	3	4
0	97.23	555	91.3	.94	16.1	91.1	4.3	4.6
1	.10	1	.2	2.00	0	100.0		
2	1.45	4	.7	.48	0	100.0		
3	.87	43	7.1	8.16	28.6	90.3		9.7
4	.35	4	.7	2.00	0	25.		75.0
Total	100.00	607	100.0	1.00	17.6	90.8	4.0	5.2

TABLE VII b

Effect of Debris on Ponderosa Pine Seedlings

(Pine Creek)

Class	% Total seedlings	No. live seedlings	% Survival	% Killed by 1	3	4
0	64.8	164	45.2	92.4	1.9	5.7
1	2.0	5	60.0	100.0		
2	9.1	23	43.5	92.3		7.7
3	19.0	48	39.6	87.9	3.0	9.1
4	5.1	13	15.2	90.9		9.1
Total	100.0	253	41.9	91.4	1.8	6.8

TABLE VII c

Effect of Debris on Douglas-Fir Seedlings

(Bannock Creek)

Debris	% Total area	No. live seedlings	% Total seedlings	Av. no. per unit area	% Survival	% Killed by 1	3	4
0	97.23	191	90.1	.92	33.5	86.4	9.1	4.5
1	.10	2	.9	9.00	0	100.0		
2	1.45	8	3.8	2.62	50.0	100.0		
3	.87	7	3.3	3.79	42.8	75.0	25.0	
4	.35	4	1.9	5.43	0	50.0		50.0
Total	100.00	212	100.0	1.00	33.3	85.3	9.2	5.5

The question of effect of dead protective cover on seedling survival is far from settled. This study covered an insufficient number of seedlings in most of the debris classes (see code sheet) to generalize on the results. The indications of the "seedling-stump" relationship reported by Otter is apparent only in survival of pine seedlings on the cut-over area. This may have been due to lack of sufficient data. Broadly speaking, the number of seedlings was greater and the survival was better with debris than without it. Limbs and logs appeared to offer the most efficient protection. The relatively large number of seedlings affected by some form of debris on the Pine Creek area suggests that germination and initial establishment are especially favored by its presence on a cut-over area (data on areal proportions inadequate for comparison), but no great advantage in later survival is indicated. Much additional study is needed to determine the effect of cover on the pine seedling.

Table VII shows results of protective cover in this study. The small number of seedlings in each debris classes should be observed, and if this factor is studied further care should be taken to obtain a more uniform distribution.

Surface

An attempt was made to classify the seedlings as to "soil surface" (see code sheet). An insufficient variation was obtained except in the case of "litter and mineral soil" (5), and "5 S" or 5 in skid trails in Pine Creek. With a basis of 188 pine seedlings in "5" and 40 in "5 S", the survival percent for the former was 37.7 percent and for the latter 77.5 percent. From these figures it is surmised that disturbed soil exerts a very favorable influence upon survival of ponderosa pine seedlings during their first year.

Litter Depth

TABLE VIII a

Effect of Litter Depth on Ponderosa Pine Seedlings

(Bannock Creek)

Depth*	% Total area	No. live seedlings	% Total seedlings	Av. no. per unit area	% Survival	% Killed by 1	3	4
0		3	.5		33.3	50.0	50.0	
1	28.0	110	17.9	.64	38.2	77.0	4.4	18.6
2	26.5	161	26.2	.99	17.4	83.8	4.5	11.7
3	28.7	183	29.6	1.03	9.3	83.4	3.8	12.8
4	13.9	100	16.2	1.17	13.0	87.6	3.5	8.9
5	2.9	52	8.5	2.93	15.4	72.4	1.3	26.3
6		7	1.1		14.6	100.0		
Total	100.0	616	100.0	1.00	17.6	90.2	4.2	5.6

* See code sheet for class definitions.

TABLE VIII b

Effect of Litter Depth on Ponderosa Pine Seedlings

(Pine Creek)

Depth	% Total area	No. live seedlings	% Total seedlings	Av. no. per unit area	% Survival	% Killed by 1	3	4
0		3	1.2		0	100.0		
1	24.6	72	28.5	1.16	50.0	92.0	2.3	4.7
2	39.2	51	20.2	.52	56.9	96.0		4.0
3	23.9	58	22.8	.96	43.2	82.5	2.5	15.0
4	8.6	45	17.8	2.14	22.2	89.2	2.7	8.1
5	3.7	24	9.5	2.57	33.3	93.7	6.3	
6	0	0	0	0				
Total	100.0	253	100.0	1.00	41.9	90.1	2.4	7.4

TABLE VIII c

Effect of Litter Depth on Douglas-Fir Seedlings

(Bannock Creek)

Depth	% Total area	No. live seedlings	% Total seedlings	Av. no. per unit area	% Survival	% Killed by 1	3	4
0		7	3.2		57.2		100.0	
1	28.0	52	23.7	.85	38.5	91.2	5.9	2.9
2	26.5	60	27.4	1.03	28.3	88.7	4.5	6.8
3	28.7	54	24.8	.89	27.8	85.6	7.1	7.1
4	13.9	32	14.5	1.04	35.0	85.0	10.0	5.0
5	2.9	9	4.1	1.41	44.4	100.0		
6		5	2.3		20.0	33.3	11.1	55.6
Total	100.0	219	100.0	1.00	33.3	83.6	8.2	8.2

The apparent increase in the occurrence of seedlings with increased litter depth, as brought out in table VIII, is undoubtedly due, in a large measure, to deep litter occurring beneath good seed trees. It was noticeable in the field that where seeding conditions were equal, under the same tree, seedlings were in greatest abundance wherever the litter was less deep. Table VIII may be somewhat misleading if considered by itself, in that it assumes areas of different litter depths have the same chance of receiving seed, which assumption is obviously at fault. However, the relationship brought out there can hardly be overlooked. A comparison of tables VIII and XII which shows the highest occurrence near the seed tree strongly strengthens the supposition that heavy seeding more than offsets the barrier to germination that litter is believed to exert.

Seedling survival decreases slowly with increasing litter depth until it reaches a depth of about $1\frac{1}{4}$ inches. Then it appears to show a slight increase. This is likely due to increased protection to the soil afforded by deep litter.

Litter Ratio

TABLE IX a

Effect of Litter Ratio* on Ponderosa Pine Seedlings

(Bannock Creek)

Ratio	% Total seedlings	No. live seedlings	% Survival	% Killed by 1	3	4
1	9.1	56	16.1	81.5	4.7	13.8
2	23.4	145	11.0	85.8	3.9	10.3
3	21.3	132	10.6	85.7	3.3	8.0
4	23.9	148	15.5	79.6	4.1	16.3
5	22.3	137	33.6	74.5	4.3	20.2
Total	100.0	618	17.6	82.0	3.6	14.4

*Ratio of litter to duff and humus -- total = 5

TABLE IX b

Effect of Litter Ratio on Ponderosa Pine Seedlings

(Pine Creek)

Ratio	% Total seedlings	No. live seedlings	% Survival	% Killed by 1	3	4
1	4.8	12	58.3	100.0		
2	17.2	43	23.3	80.6	5.6	13.8
3	17.2	43	41.8	85.7		14.3
4	31.6	79	43.1	98.0		2.0
5	29.2	73	53.4	90.5	2.4	7.1
Total	100.0	250	41.9	92.0	1.9	6.1

TABLE IX c

Effect of Litter Ratio on Douglas-Fir Seedlings

(Bannock Creek)

Ratio	% Total seedlings	No. live seedlings	% Survival	% Killed by 1	3	4
1	7.2	15	40.0	77.8	11.1	1.11
2	17.8	37	35.1	88.9	7.4	3.6
3	19.7	41	24.4	87.1	6.4	6.5
4	26.5	55	30.9	90.4	4.8	4.8
5	28.8	60	33.3	88.1	7.1	4.8
Total	100.0	208	33.3	86.9	8.5	4.6

An attempt was made in table IX to determine the effect of "litter ratio," or the ratio of litter, duff, and humus on the seedlings. To avoid complicated tables only the litter figure was used in making up the table. It is evident duff and humus would follow an inverse trend, as the total of the three was made to equal five.

From field inspection it was noted that shallow litter was usually composed principally of light litter while deeper litter had a relatively higher percentage of humus and duff. Because of this correlation, it was impossible with the data available to measure the precise effect of litter ratio alone. However, the nature of the decomposed and partially decomposed material is such that it would be expected to retard evaporation from the soil to a greater extent than light litter of the same depth. It appears probable that seedling

survival is negatively affected by litter until it reaches a depth sufficient to conserve soil moisture. Above this point it is positively effective.

There appears to be a marked similarity between Douglas-fir and pine seedlings in their relation to "litter ratio."

Vegetative Type

TABLE X a

Effect of Vegetative Type on Ponderosa Pine Reproduction

(Bannock Creek)

Type*	% Total area	No. live seedlings	% Total seedlings	Av. no. per unit area	% Survival	% Killed by 1	3	4
1 R	14.2	31	5.1	.36	6.5	97.7		2.3
1 P	2.0	76	12.5	6.25	4.0	88.2	2.6	9.2
1 IM	4.5	29	4.8	1.07	6.9	89.7	2.7	7.6
1 M	9.3	36	5.9	.63	8.3	95.4	2.3	2.3
1 OM	2.2	14	2.3	1.05	50.0	100.0		
2 R	8.8	5	.8	.09	0	83.3		16.7
2 P	.2	0	0	0				
2 IM	2.4	8	1.3	.54	12.5	85.7	14.3	
2 M	.4	7	1.2	3.00	28.9	80.0	20.0	
2 OM	.3	0	0	0				
Bare	1.0	6	1.0	1.00	83.3	100.0		
Brush	34.9	159	26.2	.75	18.9	88.6	6.3	4.9
Grass	16.7	135	22.2	1.33	13.3	94.5	2.3	3.1
Weed	3.3	101	16.7	5.06	36.6	79.1	9.0	11.9
Total	100.0	607	100.0	1.00	17.6	90.2	4.2	5.6

* See code sheet.

TABLE X b

Effect of Vegetative Type on Survival of Ponderosa Pine Seedlings

(Pine Creek)

Type	% Total seedlings	No. live seedlings	% Survival	% Killed by 1	3	4
1 R	5.1	13	23.1	75.0	8.3	16.7
1 P	6.7	17	52.9	77.8		22.2
1 IM	4.3	11	9.1	100.0		
1 M	5.5	14	42.8	100.0		
1 OM	0	0				
2 R	0	0				
2 P	0	0				
2 IM	.4	1	0	100.0		
2 M	0	0				
2 OM	0	0				
Bare	7.1	18	55.6	80.0	10.0	10.0
Brush	24.4	62	40.3	95.4	2.3	2.3
Grass	9.9	25	56.0	83.4	8.3	8.3
Weed	36.6	93	43.0	89.6	1.7	8.7
Total	100.0	254	41.9	90.2	2.4	7.4

TABLE X c

Effect of Vegetative Type on Douglas-Fir Reproduction

(Bannock Creek)

Type	% Total area	No. live seedlings	% Total seedlings	Av. no. per unit area	% Survival	% Killed by 1	3	4
1 R	14.2	33	15.6	1.10	26.0	96.0		4.0
1 P	2.0	1	.5	.25	0	100.0		
1 IM	4.5	3	1.4	.31	33.3	100.0		
1 M	9.3	8	3.8	.41	12.5	85.8	14.2	
1 OM	2.2	0	0	0				
2 R	8.8	31	14.6	1.66	58.1	84T6		15.4
2 P	.2	0	0	0				
2 IM	2.4	10	4.7	1.96	40.0	100.0		
2 M	.4	4	1.8	4.50	50.0	100.0		
2 OM	.3	0	0	0				
Bare	1.0	3	1.4	1.40	100.0			
Brush	34.9	66	31.1	.89	37.5	79.0	14.0	7.0
Grass	16.7	34	16.1	.96	20.6	85.7	10.7	3.6
Weed	3.3	19	9.0	2.73	57.9	100.0		
Total	100.0	212	100.0	1.00	33.3	84.9	9.3	5.8

Vegetative type* is a recognized measure of the site factors, and as such may often be used to predict the success other vegetation would attain on the same area. In addition to being an expression of soil, vegetation may, through competition, keep certain species from surviving on that area; and through changes it brings about in the soil encourage the advent of others.

The highest occurrence of pine seedlings in virgin area was found in ponderosa pine pole type (table X a) followed closely by weed and mature Douglas-fir. Grass, immature pine, and overmature pine are in a medium group. Pine seedlings were particularly scarce in the pine reproduction type and in the fir reproduction, pole, and immature types. Survival on the other hand is greatest on the spots classed as no vegetative type (bare) and beneath mature pine. On the cut-over area percent survival does not appear to be greatly affected by vegetative type, because of the disturbed soil conditions, and other more influential factors.

Douglas-fir favors mature fir, fir reproduction, and bare type, both for occurrence and survival.

---

* "Type," as the term is used here, designates the form of vegetation immediately surrounding the seedling or spot being described and apparently having major influence upon it. The general forest type studied would nearly all have been classed as mature or overmature ponderosa pine.

Although this is no accurate measure of the relative severity of root competition of the overstory compared with that of the lesser vegetation (because of the complication of shade, density, litter, etc.), it is notable that survival was generally as good or better in the brush, grass, and weed types as in the timber types.

It is evident from examination of table X that sufficient seedlings were not obtained in all classes of vegetative types and the results are by no means conclusive. Additional study should be made to determine the relationship of seedlings to various vegetational types.

It may be of interest to note that during the progress of this study no seedlings were observed growing in an open cheatgrass (downy chess) type; and very few were associated with balsamroot and bitterbrush.

Shade

TABLE XI a

Effect of Shade on Ponderosa Pine Seedlings

(Bannock Creek)

Shade*	% Total area	No. live seedlings	% Total seedlings	Av. no. per unit area	% Survival	% Killed by 1	3	4
0	3.2	1	.2	.06	0			
1	33.6	47	7.5	.22	46.8	74.2	4.7	21.1
2	32.3	213	34.1	1.06	19.2	87.8	3.2	9.0
3	15.5	42	6.7	.44	11.9	71.1	13.4	13.5
4	12.6	225	36.1	2.87	13.8	84.7	3.0	12.3
5	2.8	96	15.4	5.50	11.5	82.0	1.8	16.2
Total	100.0	624	100.0	1.00	17.6	82.8	3.8	13.4

*See code sheet

TABLE XI b

Effect of Shade on Ponderosa Pine Seedlings

(Pine Creek, Southerly Aspect)

Shade	% Total seedlings	No. live seedlings	% Survival	% Killed by		
				1	3	4
0	9.5	16	56.3	80.0		20.0
1	28.9	49	40.8	78.1	6.3	15.6
2	34.8	59	33.9	95.3		4.7
3	11.4	19	63.2	100.0		
4	10.1	17	29.4	85.7		14.3
5	5.3	9	22.2	100.0		
Total	100.0	169	40.2	88.7	1.7	9.6

TABLE XI b (Continued)

Effect of Shade on Ponderosa Pine Seedlings

(Pine Creek, Northerly Aspect)

Shade	% Total seedlings	No. live seedlings	% Survival	% Killed by		
				1	3	4
0	1.2	1	0	100.0		
1	26.2	22	86.3	100.0		
2	29.7	25	56.0	81.8		18.2
3	10.7	9	33.3	90.0		10.0
4	31.0	26	19.2	90.5		9.5
5	1.2	1	0			100.0
Total	100.0	84	49.3	86.7		13.3

TABLE XI c

Effect of Shade on Douglas Fir Seedlings

(Bannock Creek)

Shade	% Total area	No. live seedlings	% Total seedlings	Av. no. per unit area	% Survival	% Killed by		
						1	3	4
0	3.2	1	.5	.16	100.0			
1	33.6	20	9.1	.27	40.0	83.3	8.4	8.3
2	32.3	76	34.7	1.06	32.9	82.3	9.8	7.9
3	15.5	17	7.8	.50	11.8	81.2	12.6	6.2
4	12.6	53	24.2	1.92	35.3	90.0	7.5	2.5
5	2.8	52	23.7	8.23	42.3	80.0	5.0	15.0
Total	100.0	219	100.0	1.00	33.3	86.9	8.5	4.6

Tables XIa, and XIb IXb show an increase in occurrence with increased shade and in contrast a sharp decline in survival percent with increased shade. Shade only in the morning or afternoon appears to be most favorable and total shade all day the least favorable for survival of the individual pine seedlings, although a greater number survived per acre under heavy shade because of the high rate of occurrence there. The low survival and occurrence shown above for "3" (midday) shade indicates that the number of hours of sunlight may be more important than the time of day it is received. Douglas-fir seedlings are favored by the heaviest shade, with poorest survival under intermediate shade.

A comparison of tables XI and XIIa would indicate that "high" or tree shade is more favorable for the establishment of both fir and pine seedlings on the virgin area than is the shade of lesser vegetation. This is probably due principally to greater amounts of seed and less intimate competition between large trees and seedlings. This should be closely observed by further study.

The effect of shade on north and south aspects on the cut-over area is somewhat different. On south exposures the percent pine survival drops off slowly with increased shade. On north aspects this is much more pronounced. Figures presented in table XIBb strongly indicate that full sunlight gives best survival on both aspects, and that at least partial sunlight is required on north slopes for survival.

Partial explanation of these observations is undoubtedly a combination of root competition and surface temperatures. Where increased shade means excessive root competition, it is apt to be more injurious than beneficial to survival. Further, it appears likely that those seedlings germinating early in the season (which are those in the warmer situations) are able to reach deeper into the soil by the time of the drought period. Consequently, they stand a better chance of surviving than those in the shade and on steep north slopes that are handicapped in the beginning by their late start.

Vegetation Density

TABLE XII a

Effect of Vegetation Density on Ponderosa Pine Seedlings

(Bannock Creek)

Density	% Total area	No. live seedlings	% Total seedlings	Av. no. per unit area	% Survival	% Killed by 1	3	4
0		50	8.0		26.0	88.6	3.8	7.6
T-2%		187	30.0		24.6	81.2	4.8	14.0
3-5%		196	31.4		16.0	79.3	2.4	18.3
6-10%		109	17.4		9.7	82.9	2.4	14.7
Total	68.0	542	86.8	1.28	18.7			
11-20%	22.3	66	10.6	.47	10.9	90.0	7.2	2.8
21-30%	9.7	16	2.6	.25	18.4	75.0		25.0
Total	100.0	624	100.0	1.00	17.6	82.4	3.4	14.2

TABLE XII b

Effect of Vegetation Density on Ponderosa Pine Seedlings

(Pine Creek)

Density	% Total area	No. live seedlings	% Total seedlings	Av. no. per unit area	% Survival	% Killed by 1	3	4
0		41	16.2		43.9	100.0		
T-2%		83	32.8		56.7	92.5		7.5
3-5%		61	24.1		36.1	86.4	4.5	9.1
6-10%		37	14.6		29.7	86.2	3.5	10.3
Total	89.2	222	87.7	.98	44.2			
11-20%	8.2	23	9.1	1.11	34.8	93.8		6.2
21-30%	2.6	8	3.2	1.23	33.3	87.5		12.5
Total	100.0	253	100.0	1.00	41.9	90.0	1.8	7.3

TABLE XIIc

Effect of Vegetation Density on Douglas-Fir Seedlings

(Bannock Creek)

Density	% Total area	No. live seedlings	% Total seedlings	Av. no. per unit area	% Survival	% Killed by 1	3	4
0		28	12.8		32.1	65.4	10.5	23.1
T-2%		61	27.8		36.1	88.4	6.9	4.7
3-5%		82	37.5		34.1	89.1	7.3	3.6
6-10%		31	14.2		25.8	87.5	8.3	4.2
Total	68.0	202	92.3	1.36	33.2			
11-20%	22.3	13	5.9	.26	38.5	75.0	12.5	12.5
21-30%	9.7	4	1.8	.19	25.0	66.7		33.4
Total	100.0	219	100.0	1.00	33.3	86.2	6.9	6.9

Table XII indicates that increased vegetative density exerts a negative influence on the occurrence of both pine and fir seedlings on the virgin area, and a positive influence on the cut-over area. From these indications it may be surmised that germination requires at least a small amount of protection on an exposed cut-over area. On the Bannock Creek virgin area adequate shade is provided by the overwood and increased density of vegetation means only increased moisture competition. Another factor possibly contributing to this difference is the fact that in a virgin forest the densest vegetation is usually in the openings between trees (thus beyond the heaviest seeding zone), while on a freshly cut-over area this condition is disrupted and irregular.

Survival was generally poorer the greater the density of vegetation. This was most obvious on north aspects, but held generally true over the entire area. The trend, however, is not as marked as would be expected and there are several exceptions to it. A better trend is evident in the densities from 0 to 10 percent than in the higher classes, possibly only because of inadquate seedling data in the latter. Some such influences as mentioned in the last paragraph may be effective here too, however. Another fact tending to obscure the true relation of survival to vegetation density is that in a forest the soil beneath many spots of apparently light density is literally filled with tree roots, which may be more serious competitors of seedlings than the lesser vegetation. Density of vegetation appears to have little relation to survival of Douglas-fir, although its relation to occurrence of this species was surprisingly strong.

It appears from this evidence that within the range of densities of lower vegetation commonly found in the pine type the unfavorable effect upon survival of the competition of vegetation for soil moisture (and occasionally light) is almost balanced by the favorable effect of protection from heat injury and drying out. (See also discussion of "shade," p. 38). This is an important point and one which can not be conclusively demonstrated by observational studies alone.

It was observed during the field study, that the nature and species of vegetation were likely a better indication of its power to compete with the seedling than its density. In a continuation of this study it might be well to observe this factor more closely. A comparison of root-depth penetration and the position of root hairs of various species in relation to those seedling laterals, would undoubtedly prove of value.

Distance from Seed Tree

TABLE XIII a

Effect of Seed Tree Zone on Ponderosa Pine Seedlings

(Bannock Creek)

Zone*	% Total area	No. live seedlings	% Total seedlings	Av. no. per unit area	% Survival	% Killed by 1	3	4
1	26.1	142	22.7	.87	14.8	86.9	3.8	9.3
2	27.1	157	25.2	.93	14.0	83.8	2.9	14.3
3	34.8	292	46.6	1.33	20.1	79.6	4.1	16.3
4	7.7	32	5.3	.69	37.6	65.5	10.4	24.1
5	1.9	1	.3	.16	0	100.0		
6	2.3		0	0				
Total	100.0	624	100.0	1.00	17.6	82.0	3.9	14.1

*See code sheet for corresponding distances from seed trees.

TABLE XIII b

Effect of Seed Tree Zone on Ponderosa Pine Seedlings

(Pine Creek)

Zone	% Total area	No. live seedlings	% Total seedlings	Av. no. per unit area	% Survival	% Killed by 1	3	4
1	12.7	48	19.0	1.50	16.3	95.6	2.2	2.2
2	14.9	61	24.1	1.62	47.6	94.2	2.9	2.9
3	37.3	92	36.3	.97	48.9	83.7	3.6	12.7
4	22.8	51	20.2	.89	51.0	90.0		10.0
5	7.5	1	.4	.05	0			100.0
6	4.8	0	0	0				
Total	100.0	253	100.0	1.00	41.9	90.2	2.4	7.4

TABLE XIII c

Effect of Seed Tree Zone on Douglas-Fir Seedlings

(Bannock Creek)

Zone	% Total area	No. live seedlings	% Total seedlings	Av. no. per unit area	% Survival	% Killed by 1	3	4
1	7.1	46	21.0	2.98	28.3	87.2	5.1	7.7
2	8.1	76	34.7	4.28	32.9	78.8	13.5	7.7
3	15.5	75	34.2	2.21	36.0	81.5	7.4	11.1
4	6.1	8	3.7	.61	25.0	100.0		
5	3.2	13	5.9	1.84	46.2	100.0		
6	60.0	1	.5	.01	(100.0)	100.0		
Total	100.0	219	100.0	1.00	33.3	86.9	8.5	4.6

The occurrence of seedlings in Bannock Creek was found to be best in zone 3 (26 to 50 feet) around the pine seed trees and zone 2 and 5 around fir seed trees, with a decrease both closer and at a greater distance from the seed tree. This was due to an excess of litter directly underneath the tree and the relatively smaller number of seeds distributed at greater distances.

On the cut-over area, where the soil and litter had been stirred by logging and the stand opened up to light, the greatest occurrence was found in zones 2 and 1. These trends of occurrence are more marked on southerly than on northerly aspects.

In general the percent survival of both pine and fir seedlings on the two areas increased with increased distance from the parent tree. These relationships are apparently tied up with litter depth on the virgin area and shade and competition on cut-over land.

It would be unsafe to generalize too freely on the basis of this record as a measure of effective seeding distance, but it does indicate that for the conditions studied seeding is very scarce beyond about 100 feet and practicably negligible beyond about 200 feet from the seed tree. It may be mentioned that this is in a region of rather gentle winds.

Seed Tree Class

TABLE XIV a

Effect of Seed Tree Class on Ponderosa Pine Seedlings

(Bannock Creek)

Tree class	% Total area	No. live seedlings	% Total seedlings	Av. no. per unit area	% Survival	% Killed by 1	3	4
1	9.6	44	7.2	.75	22.7	97.5		2.5
2	11.9	70	11.5	.97	10.0	92.4	3.8	3.8
3	21.7	241	39.7	1.83	12.7	87.8	4.5	7.7
4	17.2	44	7.2	.42	38.7	86.5	10.8	2.7
5	39.3	208	34.2	.87	26.0	90.8	3.8	5.4
6	.3	1	.2	.66	(100.0)			
7	0		0	0				
Total	100.0	608	100.0	1.00	17.6	90.4	3.9	5.7

TABLE XIV b

Effect of Seed Tree Class on Ponderosa Pine Seedlings

(Pine Creek)

Tree class	% Total area	No. live seedlings	% Total seedlings	Av. No. per unit area	% Survival	% Killed by 1	3	4
1	13.2	42	16.6	1.26	9.5	85.0	7.5	7.5
2	13.7	69	27.3	1.99	21.8	88.0		12.0
3	24.2	63	24.9	1.03	55.6	93.8	3.1	3.1
4	12.6	40	15.8	1.25	55.0	100.0		
5	34.7	39	15.4	.44	56.4	90.5		9.5
6	1.6	0	0	0				
7	0	0	0					
Total	100.0	253	100.0	1.00	41.9	90.3	2.4	7.3

TABLE XIV c

Effect of Seed Tree Class on Douglas-Fir Seedlings

(Bannock Creek)

Tree class	% Total area	No. live seedlings	% Total seedlings	Av. no. per unit area	% Survival	% Killed by		
						1	3	4
1	22.6	44	20.8	.92	27.3	97.1		2.9
2	21.7	62	29.2	1.35	45.2	73.5	20.6	5.9
3	37.2	63	29.7	.80	31.7	89.2	6.5	4.3
4	16.1	12	5.7	.35	41.7	85.7	14.3	
5	2.9	25	11.8	4.92	24.0	73.6	5.3	2.1
6	0	6	2.8		0	100.0		
7	0	0	0					
Total	100.0	212	100.0	1.00	33.3	85.7	8.8	5.5

The effect of the seed-tree class on occurrence is felt chiefly through the ability of various classes to produce a large number of viable seeds. This may not agree entirely with results shown in table XIV, chiefly because of difficulty in selection of the correct seed tree, especially in a mature virgin stand. Trees of classes 3 and 5 appeared to furnish the major portion of seed on the virgin are. The accompanying table shows classes 1 and 2 to be remarkably high.

On the cut-over area, a greater number of the poorer classes were left as seed trees because of their low merchantable value and only poorer individuals of classes 3 and 5 remain. This may largely account for lack of correlation in table XIV b.

There is no reason to suspect any relation of survival percentage or cause of death to class of seed tree; the figures are given merely to make table XIV complete and comparable with the others. Such relations as may appear to be present (as a relatively low survival for classes 1 and 2) are probably due to the litter, shade, and soil moisture conditions existing in the age-class type where each class of trees is most common.

(In this regard it might be of interest to test viability and germinative energy of seed from various classes of seed trees. There may be differences in the quality as well as the quantity of seed from different classes.)

Number of Seedlings in Group

TABLE XV a

Survival of Ponderosa Pine Seedlings
As Affected by Size of the Seedling Group
(1 or more occurring together)

(Bannock Creek)

Size of group in no. seedlings	No. groups	% Occurrence	% Survival of 1 or more seedlings
1	543	86.9	18.3
2-4	61	9.8	8.2
5-7	16	2.6	25.0
8-10	3	.5	33.3
11-13	1	.2	0
Total	624	100.0	17.6

TABLE XV b

Survival of Ponderosa Pine Seedlings
As Affected by Size of Seedling Group

(Pine Creek)

Size of group in no. seedlings	No. groups	% Occurrence	% Survival of 1 or more seedlings
1	209	82.6	44.9
2-4	33	13.0	30.3
5-7	8	3.2	0
8-10	3	1.2	(100.0)
11-13	0		
Total	253	100.0	

Table XV shows that an increase in the size of the seedling group does not proportionally increase the chance for one or more surviving. The upward trend of survival on the Bannock Creek area does suggest, however, that certain seedlings may have inherent characters which enable them to live under exact conditions where others have failed. This is evidently accomplished in spite of the extra competition for soil moisture that must be present.

The occurrence of so many of the larger groups is largely due to seeds remaining in the cones until after they fall from the tree, and to caches made by rodents. The latter point was stressed by Korstian and Baker in their article, "Is Douglas-Fir Replacing Western Yellow Pine in Central Idaho?" but its importance should not be overrated. Even if all the groups of seedlings found in this study are credited to rodents, their contribution is but a small proportion of the total.

Interrelations of Factors

In an ideal study of this kind, there would be sufficient data so distributed that the influence of variations in each factor could be analyzed with all others constant; then again with accompanying variations in each of the other factors or at least each that has any interrelations with the one being considered. Thirdly, there would be variations due to the combination with two or more other factors. Actually this is the situation in nature. It is of course impracticable if not impossible to obtain and to correlate such a quantity of data.

The alternative plan followed in this study was to use all data for the analysis of each factor, assuming that there was a uniform or random distribution of the various degrees of all the other elements through the several classes of the factor under consideration. This assumption is obviously in error in some cases; e.g., with increasing distance from seed tree there tends to be decreasing depth of litter, but with a limited amount of data it is not possible to entirely segregate the two. Analysis of several such "cross-relations" of factors was attempted, but it led in most cases to such a minute subdivision of the data that no conclusions could be drawn. As has been noted, the separation into northerly and southerly aspects was carried consistently through the study of all factors, but significant differences in direction or degree of trend appeared only in the cases of slope, shade, and vegetation density. An interrelation of shade and vegetation density was suspected, but a combined sorting of data on these two factors merely substantiated the conclusions already drawn; i.e., the trend of occurrence or survival under various degrees of shade within any given vegetation density class was similar to that for all density classes together, and vice versa. Thus, while the limitations of this sort of analysis should be recognized, it appears that the base assumption is not so seriously in error and that at least fair reliance may be placed on the indicated trends.

Statistical Measures of Correlation

The data were not well suited to statistical treatment because (1) the number of seedlings was obviously inadequate for complete representation of all combinations of factors, as mentioned above, (2) the distribution of seedlings through the several classes or degrees under each factor was far from uniform, and (3) for most elements the classes themselves were not expressible in a regular gradation of numerical values. Nevertheless, some attempt was made to obtain definite measures of the significance of results, by use of the "t" test where only two classes were being compared and by variance analysis where more than one factor was involved. For example, survival percentages on northerly and southerly slopes were compared by random sorting of the two sets of cards into groups of 17 cards each, determining survival in each group and standard deviation of survival, and relating the average difference of north and south to standard deviation of the difference. By the "t" test the difference was barely significant. Variance analysis of survival percentage by aspect and slope classes, using all cards in each group, failed to show a statistically significant relationship with either factor. Because of the doubtful applicability of the method and the fact that at best only general trends and relations could be hoped for in the study, similar analyses for most other factors were not attempted.

Advance Reproduction

A tally of advance reproduction on the two areas was made in conjunction with the other areal data by individual study of a 2-milacre plot on each chain. In Bannock Creek 10 additional plots to those used for the seedling data were analyzed, which accounts for the slight discrepancies in areal percentages that may appear. The actual average number per acre were as follows: Bannock Creek: pine - 1,089, fir - 1,123, total - 2,212; Pine Creek: pine - 946, fir - 147, total - 1,093.

Advance pine reproduction on the two areas is shown in table XVI in terms of number of seedlings per unit area in relation to slope and aspect. In Bannock Creek a decided preference is shown by both pine and Douglas-fir for gentle slopes on the south exposures and for steep slopes on north exposures. This may be explained in part by the greater protection afforded on steep north slopes and the favorable seedbed exposed on gentle south slopes. It is not believed that this approaches a complete explanation.

Both species show preference for north exposures as indicated by the total figures in the accompanying table. This is much more pronounced with Douglas-fir on both areas.

The Pine Creek data, although appearing much more erratic, contain somewhat the same trend as Bannock Creek. Large deviations, both on the SE and NW aspects are difficult to account for on the basis of the factors under consideration.

It is difficult to compare these results with those shown for new seedlings in tables III and IV, as the "occurrence" of older reproduction is a resultant of both initial occurrence and later survival. The abundance of pine on gentle southerly slopes is in line with the large initial number and moderate survival there. Evidently on these areas the relatively high rate of survival on north slopes more than compensates for the scarcity of initial number of pine seedlings, resulting in a greater final number. All other permanent plot and other data at hand indicate that advance pine reproduction is normally more abundant on south than on north slopes, although the total for both species is usually greater on the north. As to why steep north slopes should be favored is even more of a puzzle. Most of the relationships indicated for Douglas-fir seem to be the natural results of preferences shown by 1-year seedlings of that species.

TABLE XVI

Advance Reproduction on the Pine Creek and Bannock Creek Transects**
by Aspect and Slope
(Figures given are the average number per unit area)
(Bannock Creek)

Ponderosa Pine

Aspect	Percent of Slope 0-5	6-20	21-40	41-70	70-	Total
SE	0*	.46	.72	.50		.59
S	1.30	2.10	.54			.93
SW	1.30	.89	.80	.44*		.88
W	.66	1.53	.76	.84		.97
N	.46	1.89	.81	2.07		1.47
NE		.92	.92	1.52		1.19
E	0	.46*	1.15	1.59		1.27
NW	0	.96	.93	.81		.95
Southerly	.98	1.26	.72	.58		.87
Northerly	.15	1.30	.92	1.39		1.14

**Based on a tally of a 2-milacre plot at the end of each chain of transect. Three hundred and twenty plots were used in Bannock Creek and 268 in the Pine Creek area.

* Based on only one 2-milacre plot.

Douglas Fir						
Aspect	0-5	6-20	21-40	41-70	70-	Total
SE	0*	.44	.03	.04		.09
S	.30	.06	.20	0		.15
SW	.15	0	0	.43*		.02
W	.19	.03	1.37	.33		.67
N	0	.44	1.62	2.53		1.64
NE		.89	2.76	5.25		3.72
E	0	.89*	.52	.92		.73
NW	0	.69	.80	2.78		1.46
Southerly	.19	.06	.48	.18	0	.26
Northerly	0	.62	1.22	2.73		1.72

* Based on only one 2-milacre plot.

TABLE XVI - cont'd

(Pine Creek)

Ponderosa Pine

Aspect	0-5	6-20	21-40	41-70	70-	Total
		Percent of Slope				
SE		0	.09	1.59*		.16
S	0	1.32	.35	.18		.81
SW	1.76	.53	.68	.26		.60
W	0	1.21	.51	.62	0*	.78
N	1.32	.56	2.82			1.23
NE		1.90		1.32		1.74
E	.53*	.18	.72	2.12*		.69
NW		5.95	.76			3.73
Southerly	.48	.98	.50	.44		.68
Northerly	1.19	2.57	1.22	1.59		1.91

* Based on only one 2-milacre plot.

Douglas-Fir

Aspect	0-5	6-20	21-40	41-70	70-	Total
SE		0	0	0*		0
S	0	.99	0	0		.53
SW	0	.85	.60	0		.53
W	0	1.09	.23	0	3.39*	.57
N	0	4.06	9.05			4.81
NE		2.04		11.87		4.85
E	0*	0	.61	0*		.42
NW		0	1.13			.48
Southerly	0	.91	.31	0	3.39	.51
Northerly	0	2.04	2.74	7.92		2.44

* Based on only one 2-milacre plot.

Summary

Observations on 624 ponderosa pine and 219 Douglas-fir seedlings on the Bannock Creek virgin area and 253 pine seedlings on the Pine Creek cut-over area were made during the summer of 1935. The principal purpose was a field study of factors influencing the occurrence and survival of seedlings up to the winter of their first year. This study of individual seedlings and their habitats brought out the following facts:

1. Twice as many pine seedlings occurred per acre under the virgin forest as on the cut-over area. Survival at the end of the season was greater on the cut-over than on the virgin area for the average acre.

2. In Bannock Creek the occurrence of pine seedlings on the south was three times as great as on north aspects. In Pine Creek the occurrence was greater on north aspects. Under both conditions the percent survival was higher on more protected north aspects.

3. Preference is shown both as to occurrence and survival by pine seedlings for the more gentle slopes. Douglas-fir occurred chiefly on steep slopes, but survived best on the more flat areas.

4. Soil Depth exerts marked influence on occurrence of seedlings on the virgin area, but is outweighed by other influencing factors in Pine Creek.

5. Pine seedlings prefer light, sandy, well-drained soils. Douglas-fir seedlings were more confined to loam type soils near creek bottoms and in other relatively moist situations.

6. Limbs and trash (debris "3") are most favorable as dead protective cover for the seedlings of both species in Bannock Creek. Stumps and logs give favorable results in Pine Creek.

7. Both pine and Douglas-fir seedlings survive best where the soil is not covered with litter. The survival decreases with increased litter depth to about 0.6 inch. Survival increases as the litter depth exceeds this amount.

8. The ratio of light litter to duff and humus is closely tied up with litter depth and shows a similar relationship to seedling survival.

9. In general "tree type" and "brush-weed type" are about equally favorable for occurrence and survival of seedlings during the first year. "Bare," "weed," and the "mature," "overmature," and "pine pole" types are most favorable, while "reproduction" types are least favorable.

10. Heavy shade is conducive to greater seedling occurrence, while a reverse relationship is true as to percentage survival. The net effect is a trend toward a greater number of surviving seedlings per acre at the end of the year with increased shade. The unfavorable effect of shade upon pine survival is more evident on north aspects. Number of hours shaded appears to be a better index as to the effect than time of day shaded.

12. Both species of seedlings occur in greatest abundance beneath the tree crown, but the percent survival increases steadily with an increased distance from the parent tree.

13. Increased vegetation density exerts a negative effect on occurrence of seedlings in Bannock Creek and a slightly positive effect in Pine Creek. Seedling survival decreases slowly with increased density of vegetation, this trend being more in evidence at lower densities and on north aspects.

14. The percent survival of pine seedlings was twice as great on the cut-over area on soil disturbed by logging as on undisturbed soil.

15. Lack of moisture is the principal contributing factor causing death of the seedlings during the summer months. It is often altered to a large extent by the presence or absence of other factors.

16. Available soil moisture is very low on these areas during the summer months. As this is commonly the limiting factor, the influence of the various environmental factors may most often be measured in terms of how they affect the soil moisture.

17. Increasing the number of pine seedlings in a group does not proportionally increase the chance of one or more surviving. A slight increase was noted in Bannock Creek, and a decrease indicated in Pine Creek.

A study of older advance reproduction shows the following relationships:

1. Ponderosa pine reproduction shows a slight preference for north aspects in Bannock Creek and three times as much on north as on south aspects in Pine Creek. Douglas-fir shows a very decided preference for north aspects on both areas.

2. In general the greatest amount of reproduction of both species occurred on gentle south slopes and steep north slopes.

Conclusions and Applications

From the data presented in this study it is believed that the following general conclusions may be made.

1. Although 1934 was an exceptional seed year only 16.2 pine and 10.7 fir in Bannock and 20.1 pine and 4.1 fir seedlings per acre in Pine Creek survived until October 10. Heavy seed years occur in ponderosa pine only once in several years. On this basis it appears unreasonable to depend on subsequent reproduction to replace virgin forest within a reasonable period.

2. It appears logical, therefore, that the safest and most inexpensive method of reproducing a stand of this nature would be to encourage the advent of advance reproduction as an understory and prevent undue injury at the time of logging. Subsequent reproduction would then be relied on only to fill the openings that inevitably occur.

3. It has not been demonstrated that clear-cutting with scattered seed trees will adequately restock an area of this kind within a reasonable length of time. On the basis of this study it appears probable that reproduction could be encouraged by substitution of partial cutting for the scattered seed tree method.

4. The effects of partial cutting (as compared to virgin forest) favorable to seedlings would then be: increased light and heat, less root competition from trees, disturbed soil conditions, and increased number of small limbs and stumps for protection. While an increased amount of evaporation from the soil would result it is likely this would be largely compensated by lessened draw on soil moisture by transpiration because of fewer trees.

5. Soil Moisture is undoubtedly the most important single factor in establishing reproduction. From relationships shown in this study light is probably next in importance. The chief method available for their regulation in the forest is by varied methods of cutting, logging, grazing, etc., and their influence on vegetative and dead protective cover.

6. Any method of cutting, grazing, or logging that will increase light, soil temperatures, disturbed soil, or dead protective cover, or decrease plant competition and litter depth, without unfavorably affecting the available moisture and the seed supply, would be expected to exert a beneficial influence on seedling establishment.

7. This study represents only a local area during one season. Additional study should be made on other areas and also in various other stages of the climatic cycle. Similar conditions over an extensive area would indicate a light to moderate partial cutting in preference to scattered seed trees. On exposed sites a selective cutting during the fall of a good seed year might be of advantage where it is economically possible.

Final copy typed: May 19, 1943

May 5, 1943

Supplementary Note

The limitations of this study have been stated in the body of the report. The various phases of the natural reproduction study which have been investigated in the years following this preliminary study have substantiated some of the relationships indicated here and have disproved others or at least have placed them in a different light. Several factors have been at least partially segregated and quantitative measurements of their effects obtained. The high importance of soil moisture as a basic factor has been repeatedly emphasized. However, the problem still remains a complex one, and the wide variation in germination and survival under conditions that appear similar makes the solution difficult.

The results of this study did serve its purpose as a guide to more intensive factor studies and will further be useful in linking up the findings of the latter experiments with extensive natural conditions. It is fortunate, however, that the report was not published in its present form as considerable retraction and re-explanation would have been required later. Most of the major conclusions still hold true but would need some modification or restriction. The authors indulged their imaginations liberally in devising explanations or interpretations of the tabulated results or of apparent exceptions to the general trends. In the light of further knowledge many of their statements appear as erroneous deductions or at least require much revision. There was also a tendency to state the local results or their interpretations as universal truths. (For an office report

this may be excusable, as it avoids qualifying every statement with such phrases as, "for the conditions of this study," or similar expressions.)

It is not the purpose of this note to discuss specifically the relationships which would be changed by later findings. All this will appear in the final comprehensive report on natural reproduction of ponderosa pine. In fact, it would be premature to state "revised conclusions" now, as they will probably be further revised after the analyses of later studies are completed. Thus the report, which has been in rough draft form since 1936, is presented as originally written and should be taken as of that date and with all its limitations recognized.

Edwin L. Mowat